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Contamination of Vegetation by Lead and Other Elements in the Vicinity of Toronto Refiners and Smelters Limited, 28 Bathurst Street, Toronto - 1986, 1987

Introduction

The Phytotoxicology Section has conducted surveys of vegetation and/or soil contamination near Toronto Refiners and Smelters (TRS) annually since 1972. Results of tree foliage sampling conducted in 1985 and earlier years have revealed elevated levels of lead, arsenic, antimony and cadmium relative to the Gerrard Street Control Area in Toronto. Average foliar lead levels near TRS in 1985 were considered to be the highest measured of any year since at least 1977.

Methods

In September of 1986 and 1987, samples of Ailanthus foliage were collected from 11 or 13 stations in the vicinity of TRS (Figure 1), from the sides of trees facing the company. Control samples of Ailanthus foliage also were collected in September of each year from 10 stations in the Gerrard Street Control Area in downtown Toronto (Figure 2).

In addition to vegetation sampling, soil sampling at each station (0-5 cm depth) was carried out in 1986. The results (not shown in this report) verified the high soil lead concentrations measured in 1985 along the railway embankment south of the Toronto Refiners & Smelters baghouse. However, considerable spatial variability in contaminant concentrations also was apparent. Soil sampling at each station was not conducted in 1987. A separate and extensive soil sampling program, focussing mainly on residential properties, was carried out in the area that year, and results have been reported separately (ARB-094-88-Phyto).

Distance and direction of sampling stations were calculated with reference to the main baghouse, which is indicated by a star in Figure 1.

Samples were processed in the Phytotoxicology laboratory, and were analyzed for lead (Pb), arsenic (As), cadmium (Cd) and antimony (Sb), all of which are potential emissions from TRS, by the MOE Laboratory Services Branch.

In this report, tree foliage results are compared with those of earlier years and with Phytotoxicology Section "upper limits of normal" (ULN) guidelines (non-legally enforceable) which were developed statistically (mean plus three standard deviations) from data for urban samples not considered to be influenced by emissions from industrial point sources. Comparisons also are made with other air quality monitoring results (dustfall and suspended particulate).

Results

Lead

Lead concentrations in unwashed Ailanthus foliage samples collected near TRS in 1986 and 1987 are shown in Table 1, and are compared with prior years' results. Average lead levels and percent of stations which exceeded the foliar guideline are illustrated in Figure 3. Whereas the 1985 levels were considered to be the highest, on average, of any year since at least 1977, concentrations subsequently decreased; 1986 and 1987 levels were similar to the mean for the results previous to 1985 (126 µg/g). However, in spite of this seeming improvement, 7 of 11 sampling stations (64%) in 1987 and 6 of 10 (60%) in 1986 revealed foliar lead concentrations in excess of the ULN guideline of 60 µg/g Pb.

Moreover, a comparison of the mean results within the TRS sampling area with those of the Gerrard Street Control Area (Table 4) reveals that tree foliage within the TRS area contained lead levels 15 and 12 times higher than corresponding samples from a typical control area in 1986 and 1987, respectively. Elevated lead concentrations were measured at distances up to 170 m E and 145 m WSW of the main baghouse. These sites are located to the E and W of Bathurst and Tecumseth Streets, respectively. No significant foliar contamination was detected to the N of Niagara Street.

Sources of Lead in Foliage

The major source of lead in *Ailanthus* foliage near TRS is believed to be direct deposition of air-borne lead emitted from the smelter operations. The main evidence for this is the pattern of contamination. The second most important source is re-entrainment of contaminated soil and dust. Re-entrainment can be estimated by using concentration ratios of tracer elements to contaminants in surface soil and foliage. In 1983, it was estimated by this technique that re-entrainment could account for an average of 24% of lead in unwashed *Ailanthus* foliage collected at the TRS sampling stations. However, the calculations showed that it was theoretically possible to account for all of the lead contamination of *Ailanthus* foliage at highly contaminated locations along the railway embankment south of TRS on the basis of re-entrainment alone.

A significant portion of foliar lead contamination can result from general urban sources. In 1986 and 1987, the average lead concentration in control area *Ailanthus* foliage (9 µg/g; Table 1) expressed as a percentage of the TRS-Mean averaged 7%, whereas prior to 1985 this percentage has averaged over 20%. Direct root uptake of lead from contaminated soil also can be an additional source of foliar lead; however, in view of the low degree of availability of soil lead for uptake by plants, as evidenced by numerous reports in the literature, this pathway is regarded as minor.

Effect of Rainfall

Amount and timing of rainfall can influence contaminant concentration results for unwashed tree foliage. In order to determine whether the measured reductions in foliar lead levels near TRS from 1985 to 1986 and 1987 could be ascribed to rainfall differences, rainfall statistics were examined. The figures in Table 2 show variations in rainfall, as measured at Pearson Airport, for the period 1977 to 1987. Total rainfall for the 2-week and 5-day periods preceding the TRS sample collection dates are shown. The correlation coefficient between the 2-week rainfall and average foliar lead concentration was -0.08 (no relationship), while that between 5-day rainfall and foliar lead was -0.52. Although not significant at the 5% level, the latter correlation does indicate that rainfall prior to sample collection may slightly reduce foliar lead concentrations (as expected). These findings are supported by earlier results from an experiment conducted near the Canada Metal Company in Toronto in 1986. That study indicated that substantial variations in rainfall (to ± 100% of mean values) in the 2-week and 5-day periods prior to sample collection exert a fairly small washing effect (up to approximately 15%) on measured tree foliage lead concentrations. The 5-day period rainfall/concentration relationship was slightly more significant than the two-week period relationship. It was determined from the results of this experiment that foliar lead concentrations were reduced by approximately 2.2% for every 10 mm of rain in the 5-day period preceding sample collection.

In view of the above, the increase in average foliar lead levels which occurred in 1985 near TRS and subsequent decrease in 1986 and 1987 cannot be ascribed to rainfall differences.

Comparison With Air Quality Monitoring Results

The Ministry of the Environment maintains a network of "hi-vol" (to measure total suspended particulate or TSP) and dustfall samplers in the vicinity of Toronto Refiners & Smelters (Figure 4). Dustfall and TSP lead results are compared with foliar lead levels near TRS in Figure 5. The selection of the two-month August to September period for comparison of air quality results was made on the basis of data availability and degree of agreement with tree foliage results. There appears to be only marginal agreement in year-to-year variation in lead results as obtained by these three techniques, although the correlation between dustfall and foliar lead is highly significant ($p \leq 0.01$). The high foliar lead concentrations measured in 1985 are not well supported by the dustfall and TSP results. By the same token, the high TSP lead levels measured at Sta. 31085 in 1984 are not supported by the other monitoring data. A large reason for the rather marginal agreement among techniques may be differences in locations of monitoring sites. For example, there are no dustfall or suspended particulate monitors located along the south perimeter of the TRS property, where the highest lead levels in foliage are routinely measured. The data are in general agreement on one significant point, however, this being the absence of any overall trend toward decreasing growing season lead levels between the late 1970's and 1987. Both dustfall and suspended particulate lead levels near TRS have been and continue (through 1987) to be well in excess of "urban background" levels of approximately 10 $mg/m^2/30d$ and 0.2 to 0.4 $\mu g/m^3$, respectively, although exceedances of the MOE air quality criterion of 5 $\mu g/m^3$ /24 h are infrequent.

Arsenic, Cadmium, Antimony

Arsenic, cadmium and antimony results for *Ailanthus* foliage collected near TRS in 1986 and 1987 are summarized, with previous years' results, in Table 3. In both 1986 and 1987, as in previous years, concentrations of all three contaminants significantly exceeded control area levels (Table 4) and ULN guidelines (Table 3), with the greatest differences and exceedences existing for antimony.

In general, distributions of these three contaminants in foliage were similar to those for lead, with the highest levels being found in samples collected along the embankment to the south of TRS, and lower levels present at stations located at greater distances from the smelter. However, considerable year-to-year differences are apparent. For example, the high foliar lead levels measured in 1985 are somewhat paralleled by elevated arsenic and antimony levels compared with 1984, 1986 and 1987; whereas, the 1983 levels of these other contaminants were as high or higher than the 1985 levels. Also, the highest average foliar cadmium concentration was found in 1986, as opposed to 1985 or 1983. These results imply varying ratios of contaminant levels in emissions from TRS which may reflect similar variations in composition of the material being processed (used batteries).

Summary

Concentrations of lead, arsenic, cadmium and antimony in unwashed *Ailanthus* foliage collected near Toronto Refiners and Smelters in 1986 and 1987 were significantly elevated compared to corresponding results from the Gerrard Street Control Area and to Upper Limits of Normal guidelines established by the MOE. Although average foliar lead levels in both years were considerably lower than the high concentrations that had been measured in 1985, there has been no overall trend toward decreasing lead levels in TRS foliage samples between the late 1970's and 1987. This lack of any apparent significant improvement in the status of lead contamination from TRS during this period also is evidenced from the results of dustfall and total suspended particulate monitoring.

In a review of the results presented in this report, experts from the MOE Hazardous Contaminants Co-ordination Branch expressed concern regarding the human health significance of exposure to the elevated lead levels.

Under the terms of an expropriation agreement with the City of Toronto, TRS vacated the property on February 19, 1989. A steering committee has been formed to oversee the demolition of structures on the site and the actual decommissioning.

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Table 1

Lead concentrations (µg/g, dry wt.) in unwashed Ailanthus foliage collected in September of 1977 and 1979 through 1987 in the vicinity of Toronto Refiners and Smelters

Station No.	Approximate Distance (m) and Direction from Main Baghouse	Lead Concentration 1977	1979	1980	1981	1982	1983	1984	1985	1986	1987
8	150 NNE	71	129	49	54	33	70	56	82	26	36
10	330 NNE	34	133	28	17	16	25	22	48	20	16
52	550 NNE	-	-	-	-	-	-	(30)	(26)	(21)	(13)
1	125 NE	272	217	125	310	81	727	240	410	185	165
4	450 ENE	65	41	12	33	24	27	26	30	26	15
50	130 E	310	162	92	126	81	95	190	1050	230	170
51	170 E	-	-	92	36	50	160	400	160	105	100
43	70 ESE	427	247	111	115	44	163	98	410	275	370
36	30 SSW	-	320	99	149	113	85	140	185	235	150
30	145 WSW	241	93	58	43	74	91	63	410	-	150
29	50 NW	191	113	88	413	131	273	250	140	175	205
24	225 NW	43	77	32	17	16	23	29	40	20	17
53	70 WSW	-	-	-	-	-	-	-	-	-	(60)
TRS - Mean (excl. bracketed values):		184	153	71	119	60	158	138	270	130	127
- Minimum ("):		34	41	12	17	16	23	22	30	20	15
- Maximum ("):		427	320	125	310	131	727	400	1050	275	370
Control Area - Mean (Ailanthus foliage):		40	54	21	18	15	20	16	20	8	10
% of TRS stations (excl. bracketed values) exceeding current "upper normal" level* (underlined):		78	90	55	45	45	73	64	73	60	64

*Note: - Phytotoxicology Section "upper limit of normal" lead concentration in unwashed urban tree foliage is 60 µg/g.

Table 2

Rainfall Statistics (Pearson Airport)

Year	Vegetation Collection Dates (TRS)	Rainfall in 2-week period prior to sample collection (mm)	Rainfall in 5-day period prior to sample collection (mm)	Average lead concentration (µg/g, dry wt.) in unwashed TRS tree foliage samples
1977	Sept. 29, 30	90.5	26.9	184
1979	Sept. 18	42.7	36.6	153
1980	Sept. 24	35.9	19.3	71
1981	Sept. 23	20.4	15.8	119
1982	Sept. 28	66.8	35.2	60
1983	Sept. 14, 15	1.2	0	158
1984	Sept. 12	52.9	27.1	138
1985	Sept. 18	36.0	0	270
1986	Sept. 17	117.0	20.5	130
1987	Sept. 16	47.6	39.4	127

Table 3

Summary of arsenic, cadmium and antimony levels (µg/g, dry weight) in unwashed tree foliage near Toronto Refiners & Smelters - 1983 to 1987

Statistical Parameters	Arsenic	Cadmium	Antimony
1983 TRS - Mean:	4.6	0.62	7.1
- Minimum:	0.36	0.1	0.29
- Maximum:	33.7	2.4	48.2
Control Area Mean:	0.11	<0.1	0.09
% of TRS stations with "above-normal" concentrations:	45	0	73
1984 TRS - Mean:	0.94	0.24	2.7
- Minimum:	0.22	<0.1	<0.03
- Maximum:	2.1	0.5	6.7
Control Area Mean:	0.14	<0.1	0.06
% of TRS stations with "above-normal" concentrations:	9	0	73
1985 TRS - Mean:	3.4	0.78	7.0
- Minimum:	0.47	0.1	0.36
- Maximum:	6.6	2.3	19.4
Control Area Mean:	0.14	<0.1	0.12
% of TRS stations with "above-normal" concentrations:	45	0	91
1986 TRS - Mean:	1.9	2.3	3.7
- Minimum:	0.25	0.1	0.25
- Maximum:	4.0	17.0	9.3
Control Area Mean:	0.13	<0.1	0.07
% of TRS stations with "above-normal" concentrations:	55	18	91
1987 TRS - Mean:	1.2	0.7	2.7
- Minimum:	<0.30	0.1	0.26
- Maximum:	3.0	3.0	7.5
Control Area Mean:	<0.3	∿0.1	∿0.3
% of TRS stations with "above-normal" concentrations:	23	8	85
Phytotoxicology Section "upper limit of normal" concentrations in unwashed urban tree foliage	2	3	0.5

Table 4

Comparison of TRS - Mean Data with Control Area-Mean: 1986,1987

Year	Factor by which TRS Sampling Area Mean Exceeds the Corresponding Control Area Mean - Unwashed Tree Foliage			
	Pb	As	Cd	Sb
1986	15	14	>22	52
1987	12	>3	∼6	∼8

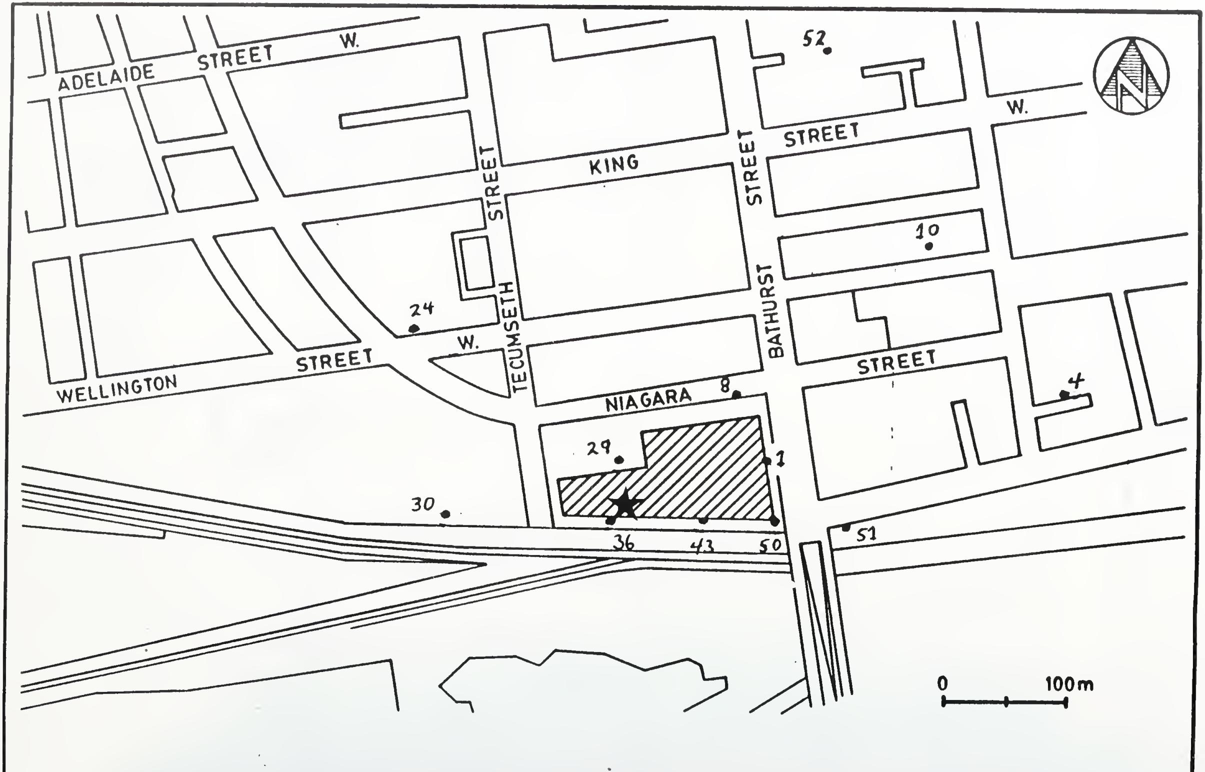


Fig. 1. VEGETATION AND SOIL ASSESSMENT SURVEY SAMPLING SITES IN THE VICINITY OF TORONTO REFINERS & SMELTERS

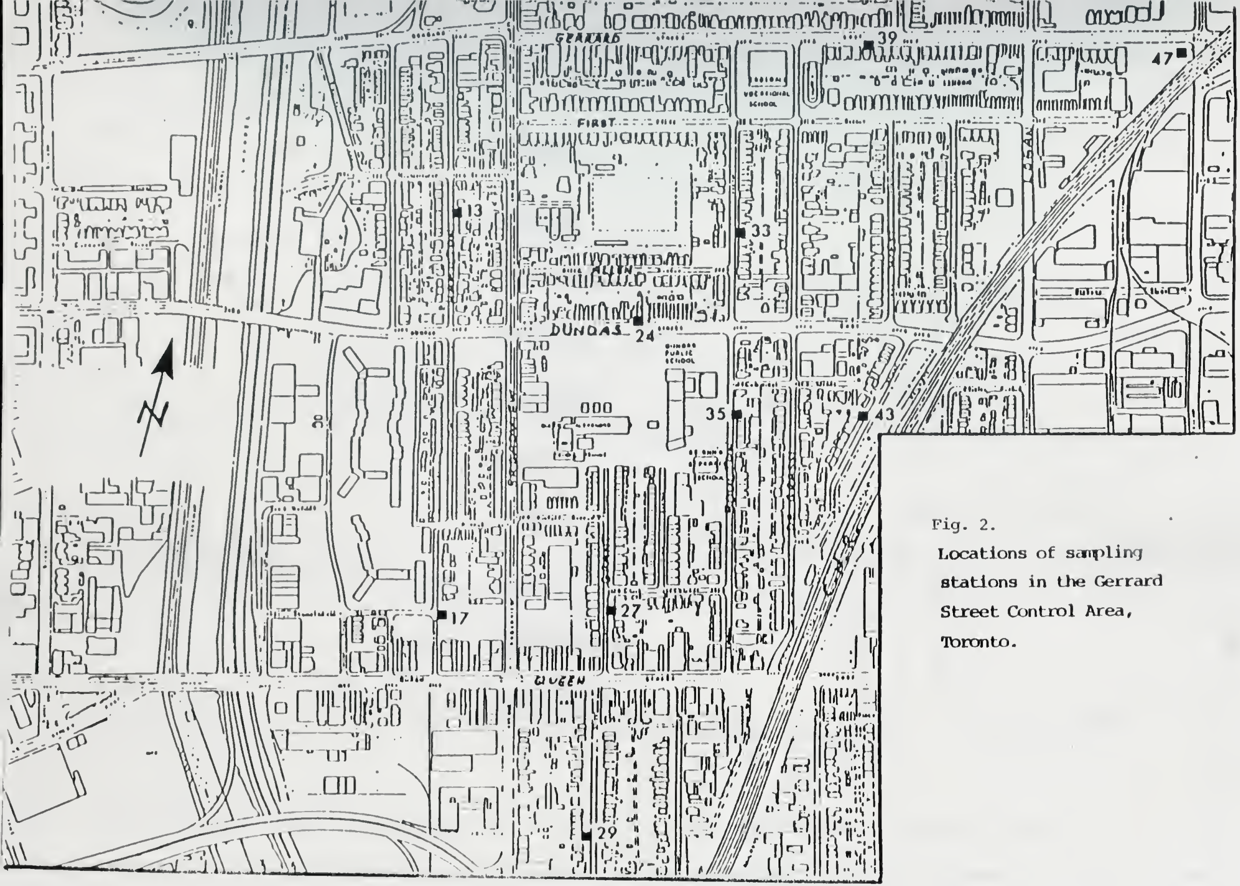
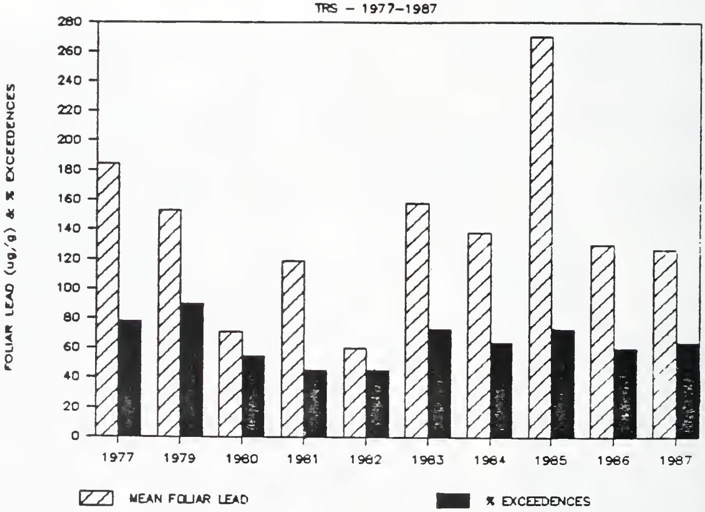


Fig. 2.
Locations of sampling stations in the Gerrard Street Control Area, Toronto.

Fig. 3.

Mean Foliar Lead & % Exceedences



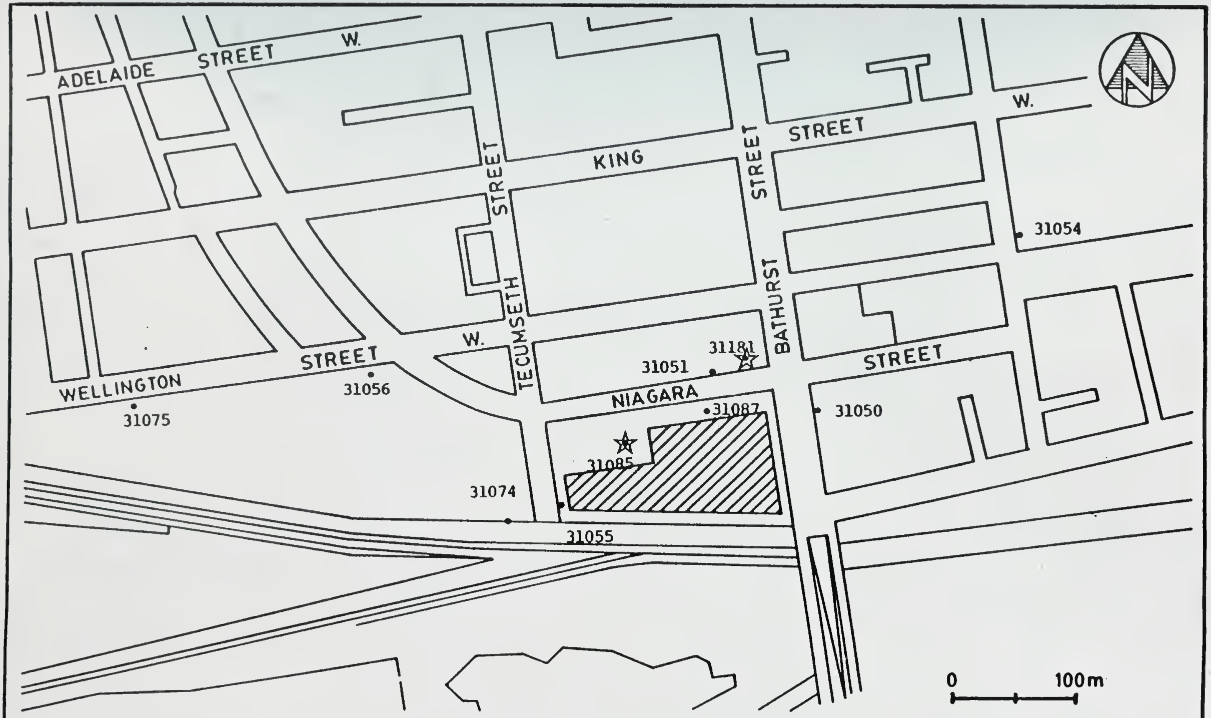
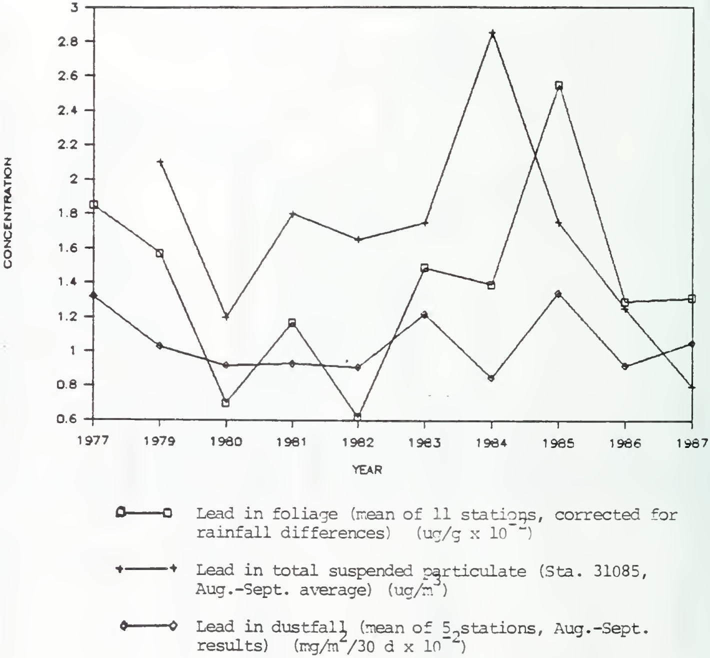


Fig. 4. Dustfall collectors near Toronto Refiners & Smelters. Star indicates hi-vol sampler also present.

Fig. 5.

Lead in Foliage, TSP and Dustfall

TRS – 1977–1987



3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
CONCENTRATION
1977
1979
1980
1981
1982
1983
1984
1985
1986
1987
YEAR
Lead in foliage (mean of 11 stations, corrected for rainfall differences) (ug/g x 10^{-2})
Lead in total suspended particulate (Sta. 31085, Aug.-Sept. average) (ug/m^3)
Lead in dustfall (mean of 5 stations, Aug.-Sept. results) (mg/m^2/30 d x 10^{-2})